

NEW GENERA OF CLADOCHYTRIACEAE

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The thallophytes described in this paper are believed to be fungi belonging to the family Cladochytriaceae. They all possess a definite hyphal mycelium and either terminal, subterminal, or intercalary enlargements which frequently contain spores and assumedly are sporangia. The thalli proliferate within the limy matrix of Echinoderm spicules, shells of molluscs, and foraminifera, and within the spicules of calcareous sponges. The entire fungus is buried within the substrate and communicates with the exterior only by means of single pores which open into the sporangial sacs. All the described forms were found by the writer about two years ago in calcareous Australian sand associated with such fossils as *Globigerina*, *Textularia*, *Nodosaria*, *Lagena*, and *Spiroloculina*. Their age, therefore, may range from Cambrian to recent. The samples of sand were obtained from Ward's Natural Science Establishment, Rochester, N. Y., and were collected at Ninety Mile Beach in South Victoria, Australia.¹

¹ It is to be regretted that neither the collector of these fungi, nor their exact location could be determined. The labels accompanying the samples of sand merely stated "Ninety Mile Beach, South Victoria, Australia." The party collecting these sands has died, and no additional information was available. To clear up their origin, the writer dispatched an inquiry to Sir Douglas Mawson, at the University of Adelaide, which elicited the following reply:

"The locality 'Ninety Mile Beach, South Victoria,' is not specifically correct for either of the two Ninety Mile Beaches figuring on our maps. There is such a beach at Gippsland, Victoria, where it faces the Pacific Ocean. But there is another Ninety Mile Beach in South Australia which faces the Southern Ocean, and extends east from the mouth of the Murray River.

"I can't imagine how Wards got a sample from the South Australian Ninety Mile Beach and think it most likely that yours came from Gippsland. I will therefore get in touch with F. Chapman, Palaeontologist of the National Museum, Melbourne, who is an authority on foraminifera and much interested in marine sands. He may be able to get some Gippsland beach sand for you.

"As for our Ninety Mile Beach sand I will take the first opportunity to enlist the services of any scientists going that way—and hope to procure some for you. It is an out-of-the-way place, however, there being no settlement near that long line of coast."

The type and cotype specimens have been deposited in the herbarium of the Missouri Botanical Garden, St. Louis.

The writer acknowledges his indebtedness for aid and suggestions in carrying out this study to Dr. Charles Lyman Porter, of Purdue University, and Dr. Carroll William Dodge, of the Henry Shaw School of Botany of Washington University. The photomicrographs accompanying this article are partly the work of Dr. Edwin Jacob Kohl.

DODGELLA Zebrowski, gen. nov.

Hyphae intramatrales in ostracis, ex base spherica ramosae, perpendicularibus hyphis sporangiferis; dehiscentia ignota; sporangiosporae sphaericae.

Type: *Dodgella priscus* Zebrowski.

Hyphae rarely branched, growing beneath the surface of shells and in sponge spicules, proliferating from the spherical base of the sporangia which are subterminal with the longitudinal axis at right angles to the hyphae, dehiscence unknown; sporangial neck reaching surface of the shell or spicule and opening by a pore to the outside; sporangiospores ? spherical.

This genus is closest to *Nowakowskiella* and *Cladochytrium*, but the branching is different, also the attachment of the sporangium to the hypha. This genus is named in honor of Dr. Carroll W. Dodge.

Dodgella priscus Zebrowski, sp. nov. Pl. 27, figs. 1, 3.

Thallus sphericus, levis, 2-9 hyphas gignens; sporangia 15 μ diametro, cervix ad 5 μ longitudine, apertura apicale ad 3.5 μ diametro; sporangiosporae? rarae, sphaericae, brunneae?, ad 3 μ diametro.

Thallus a simple, smooth, globular sac, about 15 μ in diameter, from which emerge 2-9 distributive hyphae; sporangial necks short, about 5 μ long, communicating with the surface by a circular aperture about 3.5 μ in diameter; sacs usually empty, occasionally showing red or brown, spherical spores? averaging 3 μ in diameter.

This interesting fungus is of wide and seemingly cosmopolitan distribution. The writer found it in sands of both fossil

and recent formations from such widely separated localities as South China Sea, South Australia, Texas (Eocene formation), Africa, and from beach sands around Beaufort, North Carolina. The specimens from the different localities vary somewhat in size, but the variations are so slight that it has not been possible to resolve them into more than a single species. This species has been found growing on the shells of molluscs and ostracoda and within the spicules of sponges (pl. 27, fig. 3).

This fungus shows a tendency toward rapid proliferation and the formation of extensive colonies, being the most abundant species. The mature sac sends off one or more reproductive hyphae from its globular base. These grow for varying distances just below the surface of the substrate and eventually each hypha produces a new sac, subterminal in position and from 5 to 15 μ back from its tip. This daughter sac then grows down into the substrate at right angles to the hypha and in turn it produces new hyphae from its globular base. Occasionally sacs are also produced at the tips of hyphae. The hyphae are about 1 μ thick, of uniform diameter, and branch but rarely.

When spores were dissolved on a slide with dilute hydrochloric acid, those from a single sac remained cemented together in a clump, some degree of force being required to separate them with a dissecting needle. Further, spores similar to those within the sacs were found scattered over the surfaces of a number of pieces of shell. Most of these spore-like bodies not only adhered to the surface, but were embedded in spherical cavities of varying depths. It seems likely that the spores secrete some substance which enables them to adhere to the shells on which they may lodge and develop. Occasionally a hypha would end in a bifurcation consisting of two comma-shaped swellings, thickest at their free ends. It is possible that these are gametangia.

Dodgella inconstans Zebrowski, sp. nov.

Pl. 27, fig. 2.

Hyphae 1 μ diametro, subramosae; sporangia 15–22 \times 27–44 μ , irregularia, subterminalia, ampulliformia, lobata, subapplanata, cervicibus perpendicularibus, ostiolis circularibus, 4 μ diametro.

Hyphae occasionally branched, $1\ \mu$ in diameter, sterile hyphae rare; young sporangia subterminal, flask-shaped, growing straight down into the substrate, the bottom soon becoming lobed or folded and usually somewhat flattened, so that the neck is at right angles to the venter, $15-22 \times 27-44\ \mu$; ostioles single, circular, averaging $4\ \mu$ in diameter; no spores seen. One large colony, however, showed the sporangia more or less completely filled with an amorphous, brown substance with black spots, resembling protoplasm.

On shells of molluscs in tidal beach sands, Beaufort, North Carolina, of recent origin.

The sporangia are extremely variable in size and shape in this species.

Dodgella radicans Zebrowski, sp. nov. Pl. 27, fig. 4.

Hyphae $1\ \mu$ diametro; sporangia $17-21 \times 27-43\ \mu$, subterminalia, pyriformia, ostiolis circularibus, $4\ \mu$ diametro, rhizoideis 4-15, plerumque 8, longitudine variabilibus, irregulariter sparsis; sporae non visae.

Hyphae of uniform diameter, about $1\ \mu$, usually 2 or 3 distributive hyphae and 4 to 15, usually 8 rhizoids to each sporangium; sporangia $17-21 \times 27-43\ \mu$, subterminal, pyriform, opening to the surface of the shell by a single circular ostiole about $4\ \mu$ in diameter; spores not seen.

In shells of molluscs in fossiliferous sands from Ninety Mile Beach, probably Victoria, Australia.

COULTERELLA Zebrowski, gen. nov.

Hyphae intramatrales praelongae, tenuissimae, in ostracis molluscorum; sporangia fusiformia vel bifurcata (literae Y similia); sporae pachydermaticae, sphaericae vel subsphaericae.

Type: *Coulterella Petersoni* Zebrowski.

Intramatrixal hyphae very long, slender, in shells of molluscs; sporangia fusiform or forked (in a single plane similar to the letter Y); spores thick-walled, spherical or flattened, abundant.

This genus differs from the preceding in the shape of its spo-

rangia which are often forked and communicate with the surface by a common pore. The genus is named for Dr. Stanley Coulter.

Coulterella Petersoni Zebrowski, sp. nov. Pl. 27, fig. 12.

Hyphae 270–730 μ longitudine, aequales, ad 1 μ diametro; sporangia 68–98 \times 20–27 μ , simplicia fusiformiaque vel bifurcata (literae Y similia), poro singulo commune aperta, ad 5 μ diametro; sporangiosporae copiosae, subapplanatae, junioribus leptodermaticis, ad 5 μ diametro, maturis pachydermaticis, ad 4 μ diametro, rubro-brunneis.

Hyphae long, 270–730 μ , uniform in diameter, about 1 μ ; sporangia 68–98 \times 20–27 μ , either simple and fusiform or proliferating in a single plane to form Y-shaped structures opening to the surface by a common pore about 5 μ in diameter; sporangiospores abundant both in the primary sporangium and its branches, somewhat flattened, thin-walled, slightly greenish in appearance, 5 μ when young, becoming thick-walled, reddish, averaging about 4 μ in diameter when mature.

Found in shells of molluscs. This species is named in honor of Prof. Perry S. Peterson.

Coulterella Petersoni is a common form resembling *Conchyliastrum Enderi* in its development. The thallus is a flattened sac, with only 1–3 similarly flattened diverticula which usually give rise to two or more distributive hyphae. The diverticula or lateral sacs are more irregular in outline in this species than they are in *Conchyliastrum Enderi*; also, two or more hyphae may emerge from each diverticulum, which was never observed in *Conchyliastrum*, where the hyphae arise singly as distal prolongations of the lateral sacs. In both genera the daughter sacs are formed one to each hypha, usually sub-terminal in position. Each daughter sac then develops into a primary sac. Each primary sac in turn gives rise to one or more lateral pouches which lie in the same plane and appear to be only prolongations of the main sac; in *Conchyliastrum Enderi* the pouches are usually at an angle or at right angles to the main sac. When only one pouch develops, the resulting thallus is fusiform, but with two

pouches, the thallus is roughly Y-shaped (pl. 27, fig. 12). The daughter thalli remain attached to the parent by means of the distributive hyphae which occasionally branch. The numerous spores of this species were found closely packed both in the primary sacs and in the diverticula. Two kinds of spores were observed, a thick-walled, red spore averaging $4\ \mu$ in diameter, and a larger, thin-walled, greenish spore $5\ \mu$ in diameter. This last was assumed to be immature. Both types are somewhat flattened.

PARAMOECIELLA Zebrowski, gen. nov.

Hyphae longae, ramosae, ramis perpendicularibus; sporangia elongata intercalaria, somati *Paramoecii* similia, levia, leptodermatica; sporae non visae.

Type: *Paramoeciella Gamblei* Zebrowski.

Hyphae branched, alternate, rarely opposite, perpendicular to the axis of the main hypha, bearing large, intercalary, elongate sporangia, shaped like the body of *Paramoecium*, but smooth and thin-walled; spores not seen.

These large intercalary sporangia, shaped like the body of *Paramoecium*, seem quite distinct from any genus so far reported.

Paramoeciella Gamblei Zebrowski, sp. nov. Pl. 27, figs. 5-6.

Hyphae $7\ \mu$ diametro, longae, infrequenter ramosae, intramatrales; sporangia intercalaria, elongata, $193\text{--}214 \times 280\text{--}962\ \mu$, somati *Paramoecii* similia, sed levia, leptodermatica; sporae non visae.

Hyphae long, $7\ \mu$ in diameter, infrequently branched, usually alternate, rarely opposite, branches at right angles to the main axis, thickened at the base; sporangia intercalary, elongate, closely resembling *Paramoecium* in outline, $280\text{--}962 \times 193\text{--}214\ \mu$, each sporangium arising as an elongate swelling on one side of a hypha, with its long axis parallel to that of the main hypha and attached at its side for about one fourth its length; hyphae occasionally seen arising directly from the sporangium (pl. 27, fig. 6); large oval aperture averaging $34\ \mu$ in width and tapering toward the sac developing at the point of contact; en-

tire thallus smooth and thin-walled, without spines or other irregularities; no spores observed.

This species was quite common and usually occurred in clusters of sporangia and hyphae as shown in pl. 27, fig. 5. It is named for Dr. Dean La Fever Gamble.

ARTHURELLA Zebrowski, gen. nov.

Hyphae intramatrales; sporangia elongata, tubularia, terminalia, longis cum cervicibus, poris apicalibus, proliferantia; sporangia partialia, spherica vel pyriformia, irregulariter distributa; sporae in sporangiis lateralibus (partialibus), sphaericae.

Type: *Arthurella Corringtoni* Zebrowski.

Hyphae intramatricales; sporangia elongata, tubular, terminal with long tapering necks, opening by an apical pore, proliferating to form spherical or pyriform, partial sporangia irregularly distributed over the primary ones; spores spherical, seen only in the lateral (partial) sporangia.

The genus is named in honor of Dr. Joseph Charles Arthur.

Arthurella Corringtoni Zebrowski, sp. nov. Pl. 27, fig. 10.

Hyphae 3–4 μ diametro; sporangia elongata, tubularia, 48–119 \times 13–24 μ , terminalia, longis cum cervicibus, poris apicalibus 5 μ diametro, proliferantia; sporangia partialia spherica vel pyriformia, irregulariter distributa, magnitudine variabilia; sporangia magna una cum partialibus echinulata; sporae in sporangiis lateralibus (partialibus) aureae, sphaericae, 3 μ diametro.

Hyphae 3–4 μ in diameter, tapering only slightly, usually thickened at point of emergence, occasionally branched, arising only from main sporangium; sporangia 48–119 \times 13–24 μ , with long tapering necks and apical pores 5 μ in diameter, proliferating to form partial sporangia which are pyriform or spherical, irregularly distributed along the main sporangium, variable in size, perhaps produced progressively as the sporangium elongates; larger sporangia and portions of adjacent hyphae covered with very small spines, observable only under high magnifications in larger specimens and assumedly char-

acteristic of maturity; lateral (partial) sporangia always much smaller than main sporangium, varying from 6 to 14; spores found only in the partial sporangia, golden in color, spherical, averaging $3\ \mu$ in diameter.

This species is named for Dr. Julian Dana Corrington.

CONCHYLLIASTRUM Zebrowski, gen. nov.

Hyphae ex apicibus sporangiorum secundariorum, longae, nova sporangia gignentes; sporangia secundaria fusiformia, elongata, radiata ex ventro globoso sporangii primarii cum ostiolo singulo cervice longa; sporae ovoideae, pachydermaticae.

Type: *Conchyliastrum Enderi* Zebrowski.

Primary sporangia subterminal, flask-shaped, with a long neck and round venter which proliferates to form long-fusiform, secondary sporangia with ovoid, thick-walled sporangiospores; hyphae arising from tips of secondary sporangia, spreading through the shell, and giving rise subterminally to another group of sporangia.

The genus name is derived from the Latin *concha* (shell) and *aster* (star).

Conchyliastrum Enderi Zebrowski, sp. nov. Pl. 27, figs. 7, 9.

Hyphae longae, 255–527 μ , ad 1 μ diametro; sporangia primaria 20 μ diametro, spherica, cervicibus cum tubularibus, 30 μ longitudine, et poris apicalibus circularibus, 5 μ diametro, proliferantia; sporangia lateralia, partialia, 2–14, plerumque 6–7, radiata, $34 \times 7\ \mu$, elongata, fusiformia vel ampulliformia; sporae 3 μ diametro, ovoideae, rubro-luteae, pachydermaticae.

Hyphae long, 255–527 μ , 1 μ in diameter; primary sporangia 20 μ in diameter, spherical, with tubular necks 30 μ long, and apical, circular pores 5 μ in diameter, proliferating; lateral or partial sporangia, 2–14, usually 6–7, radiating, $34 \times 7\ \mu$, elongate, fusiform or flask-shaped; spores 3 μ in diameter, ovoid, reddish-yellow, thick-walled.

Found in the calcareous parts of molluscan shells and in sponge spicules. This species is named for Dr. Howard E. Enders.

If the matrix is thick and permits of uncrowded development, the thallus develops a long-necked, flask-shaped, primary sac from the globular base of which radiate the lateral pouches (pl. 27, fig. 7). If, however, the matrix is too thin to permit of deep growth and normal expansion, the thallus will spread out in a single plane like the fingers of a hand (fig. 9). From the distal extremities of the lateral sacs emerge single hyphae which penetrate the matrix for long distances, eventually giving rise to new subterminal sacs (fig. 7). These daughter sacs elongate, become flask-shaped, develop lateral pouches and hyphae, and thus give rise to a new thallus.

Conchyliastrum Merritti Zebrowski, sp. nov. Pl. 27, fig. 11.

Hyphae crassae, 5–3 μ diametro, ax apicibus sporangiorum partialium proliferantes, breves; sporangia primaria clavata, intercalaria, 75 \times 30 μ , cervicibus longis, poris apicalibus 5 μ diametro, irregulariter proliferantia; sporangia lateralia (partialia) 50 \times 10 μ , fusiformia, dein irregulariter subspherica; sporae brunneae, 1 μ diametro, sphaericae, catervatae in sporangiis primariis secundariisque.

Hyphae thick, 5 μ in diameter, tapering to 3 μ , proliferating from the tips of the partial sporangia, short; primary sporangia clavate, intercalary, 75 \times 30 μ , with long necks and apical pores 5 μ in diameter, irregularly proliferating to form secondary sporangia 50 \times 10 μ , fusiform at first, becoming irregularly subspherical; spores brown, 1 μ in diameter, spherical, collected into spore balls, seen both in the primary and in the secondary sporangia.

In its general structure and development this species resembles *C. Enderi*, but there is a lack of symmetry in the lateral pouches. They seem to arise as spindle-shaped outgrowths but soon become irregularly globular, no two being alike in shape and some as large as the primary sporangium. The hyphae are relatively short and stout, emerging as prolongations of the lateral sporangia so that it is difficult to tell where they begin. They also taper in their course, being about 5 μ thick at their origins and about 3 μ at their distal ends.

This species is named for Mr. Edgar B. Merritt.

ARBORELLA Zebrowski, gen. nov.

Hyphae dichotome ramosae, rhizoideis; sporangia terminalia, spherica, poris magnis; sporae non visae.

Type: *Arborella Kohli* Zebrowski.

Hyphae dichotomously branched, bearing minute rhizoids at the nodes; sporangia terminal, large, spherical, with a large pore; spores not seen.

The generic name was given because of a fancied resemblance of this form to a branch of a tree with fruit at its extremities.

Arborella Kohli Zebrowski, sp. nov. Pl. 27, fig. 8.

Hyphae dichotome ramosae, 1.6 μ diametro, 20–70 μ inter ramis, rhizoideis ad 1 μ diametro; sporangia spherica, 10 μ diametro, poris magnis; sporae non visae.

Hyphae dichotomously branched, 1.6 μ in diameter, 20–170 μ between nodes, rhizoids about 1 μ in diameter; sporangia spherical, 10 μ in diameter, with large pores; spores not seen.

The main hyphae and branches are all about the same thickness and of somewhat irregular outline. The internodes vary in length and are thinner than the nodes. Each internode bears one or more rhizoidal hairs which penetrate the substrate and apparently emerge on the opposite side of the shell. The entire thallus lies buried within the living matrix of the shell. The sporangia are spherical with large pores of approximately the same diameter as that of the sac, which open on the same surface as the rhizoidal hairs.

This species is named for Dr. Edwin Jacob Kohl.

Arborella Calverti Zebrowski, sp. nov.

Hyphae dichotome ramosae, 1.4 μ diametro, ad 132 μ inter ramis, rhizoideis longis; sporangia elongata, irregulariter lobata, 12–33 μ diametro, sine poris; sporae non visae.

Hyphae dichotomously branched, 1.4 μ in diameter, about 132 μ between nodes, with long coiled rhizoids; sporangia elongate, irregularly lobed, 12–33 μ in diameter, apparently rupturing irregularly, without a well-defined pore; spores not seen.

The main hyphae bearing the sporangia lie beneath one sur-

face of the shell. The rhizoids arise from both nodes and internode and penetrate within the matrix, producing an abundant, tangled network of threads. Frequently a node gives rise to both a sporangiferous branch and a rhizoid.

The species is named for Dr. Phillip Powell Calvert.

EXPLANATION OF PLATE

PLATE 27

- Figs. 1 and 3. *Dodgella priscus*.
Fig. 2. *Dodgella inconstans*.
Fig. 4. *Dodgella radicans*.
Figs. 5-6. *Paramoeciella Gamblei*.
Figs. 7 and 9. *Conchyliastrum Enderi*.
Fig. 8. *Arborella Kohli*.
Fig. 10. *Arthurella Corringtoni*.
Fig. 11. *Conchyliastrum Merritti*.
Fig. 12. *Coulterella Petersoni*.